

Chapter 1: Introduction

The EMF issue has been in the environmental debate since 1979, when Wertheimer and Leeper published an article suggesting a statistical association between certain characteristics of electrical powerlines near homes and the incidence of childhood leukemia (Wertheimer and Leeper, 1979). In the following 20 years, about \$200 million of research funds were spent to determine the possible cause and effect relationship and the magnitude of this effect. In 1996, the National Research Council stated, “There is no conclusive evidence that EMF causes cancer” (National Research Council, 1996, p. 4). More recently, the National Institute of Environmental Health Sciences stated, “The scientific evidence suggesting that EMF exposures pose any health risk is weak,” but that “EMF exposures cannot be recognized as entirely safe, because of weak scientific evidence that exposures may pose a leukemia hazard” (National Institute of Environmental Health Sciences, 1999, Executive Summary, p. 1 and 2).

In 1995, the California Public Utilities Commission (CPUC) began funding a program to investigate various aspects of the EMF debate. The California Department of Health Services administered this program for the CPUC. One project, the “Power Grid and Land Use Policy Analysis,” was to examine engineering and land use alternatives that could reduce the exposure to EMFs. The objective of this project was to provide decision-makers with tools to develop and assess policy in light of the significant uncertainties about a possible EMF-health relationship. The project was not expected to provide recommendations. Instead it was expected to evaluate the costs and benefits of EMF management alternatives favored by various stakeholders and to determine what degree of confidence that a health hazard exists (if any) would be required to justify remedial actions. For those who wished to challenge the preliminary evaluations, a user-friendly computer model was developed to allow stakeholders or their technically knowledgeable advocates to modify the assumptions and to explore the consequences of these modifications.

The project considered all elements of the power grid system as possible sources of EMF exposure, including transmission lines, distribution lines, substations, and home grounding systems. The policy options include land use planning alternatives, retrofitting existing lines and facilities and re-designing new ones, standard setting, and other forms of regulation. Using decision analysis tools, the project considered a wide range of policy options, several scenarios involving a possible link between EMF exposure and health effects, and many objectives of different stakeholders. Special efforts were made to assess the environmental justice implications of policy options and to conduct a feasibility study of an assessment of property values near power lines and substations.

In the course of the project it became clear that many arguments about policy choices are really arguments about frameworks. Economists, engineers and regulatory agencies often use a predominantly results oriented “utilitarian” framework. Any given stakeholder using this framework considers his/her options along a number of criteria and chooses the option that produces the best trade-offs between the various criteria. In order

1 to find the option with the best balance of criteria, the utilitarian stakeholder may assign
2 dollar values to tangible criteria such as project costs and to intangible criteria such as
3 aesthetic consequences or human lives saved
4

5 When different stakeholders using this approach end up advocating different
6 courses of action because they have different interests, the utilitarian resolves the conflict
7 by choosing the solution that aims at producing the “most good for the most people at the
8 least cost.” Sometimes this ignores the interests of some small segment of society. On
9 many issues, members of the general public don’t adhere to the utilitarian framework.
10 Often they adhere either to a “social justice” framework that tries to fulfill duties or
11 protect rights of the vulnerable regardless of cost, a “non interference” framework that
12 tries to protect individual and property rights from governmental interference or a
13 framework that requires virtual certainty of a problem before taking action.
14

15 Adherents to the different frameworks might prefer different policy options. For
16 example if a municipality that owned its electrical utility decided that magnetic fields
17 from power lines and appliances were hazardous and wanted to do something about it,
18 the utilitarians in town might recommend that the municipal utility should pay for the
19 most cost-effective measures to reduce exposure. As a result, they may advocate
20 reducing EMF exposure from sources other than power lines, for example by replacing
21 old, high exposure electric blankets and VDTs with new, low exposure models to prevent
22 as much disease as possible due to electricity sources.
23

24 The adherents to the social justice framework might point out that the minority of
25 people living next to the power grid were still at a higher risk. They might invoke the
26 “precautionary principle” that risk avoidance policies are warranted even if there is
27 uncertainty about whether or not there is a risk. Furthermore, they might argue that
28 policy makers have a special duty to protect the minority of people exposed to the risk if
29 it had been unfairly singled out for EMF or other harmful exposure on the basis of race,
30 or had less access to medical care. From this perspective, environmental agents like EMF
31 should be treated as “guilty until proven innocent.” Therefore the people living near the
32 lines should be protected by modifying the lines to lower fields even if it was expensive
33 to do so. They might also invoke a duty of the utilities “to clean up their own mess” at
34 their expense.
35

36 The adherents to “non interference” might oppose both options because they
37 would involuntarily tax the many for the benefit of the few. Regardless of the degree of
38 confidence in the existence of an EMF hazard, they might prefer a “right to know”
39 information program to allow the free market and voluntary actions of those who were
40 concerned to solve the problem. Adherents to the “virtual-certainty-required” framework
41 would not want to take any action unless all scientists in the field were convinced of a
42 problem. For them EMFs are “innocent until proven guilty.”
43

44 There is no technical resolution to these kinds of arguments. A democracy
45 handles them through the political process. However, to address these issues, a decision
46 analysis approach was used that was designed to be useful to adherents of all frameworks

1 and to highlight issues where the different policy frameworks might lead to different
2 conclusions. The intention was to assist decision-makers to anticipate how features of
3 different policy options might be attractive to stakeholders who adhered predominantly to
4 one or the other policy framework.

5
6 The decision analytic framework used in this power grid and land use project is
7 consistent with the utilitarian framework, but it also addresses some of the concerns of
8 the three other frameworks. First, rather than assuming that EMF is or is not a hazard, it
9 asked what would be the minimum degree of confidence and the minimum magnitude of
10 risk that would warrant actions. If a protective action is very inexpensive, even a low
11 degree of confidence of a small risk can be justified in a decision analysis. If a protective
12 action is very expensive even complete confidence that EMFs cause a rare disease would
13 not be warranted from a decision analysis point of view. Second, instead of combining
14 all the costs and benefits into a single number, the results are presented separately for
15 each cost or benefit component (e.g., health cost, outage cost, property values benefits,
16 etc.) so that if some costs or benefits pertain to one party and other costs or benefits to
17 another, this is clearly presented for decision makers whose framework pays attention to
18 the distribution of costs and benefits. Third, the decision analysis framework is presented
19 in a way that allows stakeholders to use their own judgments about the facts and values
20 concerning the costs and benefits of EMF mitigation.

21 While the decision analysis approach clearly separates the sources of costs and
22 benefits, it does not make recommendations about how the costs and benefits should be
23 allocated to stakeholder groups. For example, it is conceivable that the costs of EMF
24 mitigation are allocated either to utility shareholders, the ratepayers, to residents who
25 might benefit from the mitigation, or any mix of these groups. The analysis does not
26 provide any guidance about the best allocation of costs and benefits. As a result, decision
27 makers will have to rely on ethical and moral principles when making these allocation
28 decisions. We conducted a workshop on ethics and environmental justice as part of this
29 project, and some of the findings of this workshop help (see chapter 10 of this report).

30 The project combined three approaches to address the fundamental uncertainties
31 surrounding a possible EMF-health link:

- 32 1. *decision analysis* to incorporate the uncertainties and consequences of
33 alternative policies,
- 34 2. analysis of alternative *exposure measures and dose-response functions* to
35 capture a variety of possible biological relationships between EMF exposure
36 measures and health effects,
- 37 3. a *stakeholder involvement process* to assure that a wide range of opinions,
38 values, and concerns are incorporated in the policy analysis.

Decision analysis provided the overall framework for the policy analysis. The power grid and land use policy problem was first structured as a decision tree that started with policy alternatives (e.g., to mitigate by re-phasing or re-configuring existing lines), followed by several uncertain events regarding the resolution of the EMF issue (see Figure 1). For those unfamiliar with the term “decision tree” we recommend the image of walking along a road with many forks and branches. A traveler who ventures along any of these branches will find that each of them have further branches that could represent the chance that something does or does not happen as a result of the fork of the road chosen earlier. The decision tree is kind of a map to aid in keeping track of alternatives chosen, possible events, and the ultimate consequences that could result. The decision tree in Figure 1 captures the major uncertainties about whether or not EMF exposure poses a hazard and how large the increase in risk is, measured as a risk ratio.

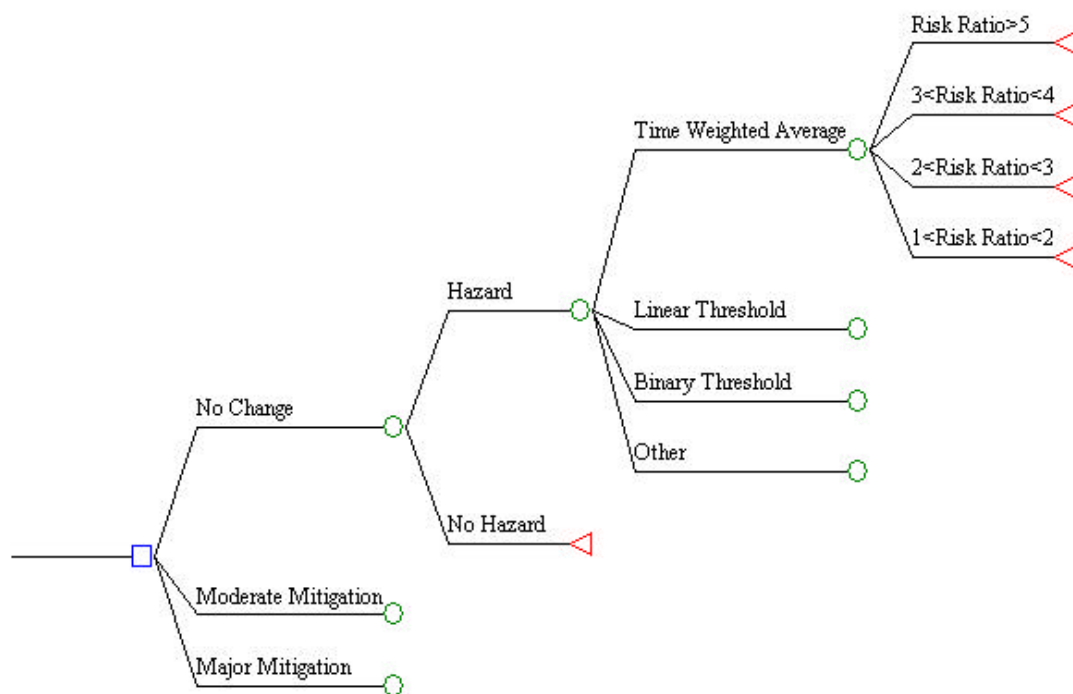


Figure 1: Schematic Decision Tree for Policy Analysis

(The square denotes a decision node, circles denote event nodes, and triangles denote end nodes at which consequences can be determined. Branches that end with a circle are completed by the tree above them.)

There also is significant uncertainty about what characteristic or measure of EMF exposure might be related to biological responses or doses. Possible measures include the

1 time-weighted average of the magnetic field or the percent of time that a person is
2 exposed to a field above a threshold. A significant effort was made in this project to
3 estimate EMF exposure for different exposure measures and with different assumptions
4 about the shape of the dose-response function.

5 At each end-node of the decision tree for which EMF is a hazard, health
6 consequences occur. The project investigated the following health endpoints for which
7 there is some epidemiological evidence of an EMF-health link: adult brain cancer, adult
8 leukemia, female breast cancer, Alzheimer's disease, childhood brain cancer, and
9 childhood leukemia. Mitigation options reduce EMF exposure and, if EMF poses a
10 hazard, they will reduce health consequences. Because of the significant uncertainty
11 about whether or not EMF is a hazard and what the magnitude of the hazard is, the
12 decision analysis model was constructed primarily to explore the implications of different
13 probabilities that a hazard exists and different degrees of severity of the hazard, if it
14 exists. The main output of the decision analyses are two-way sensitivity analyses that
15 answer the question: What is the minimum degree of confidence that a hazard exists and
16 what is the minimum size of the health effect, that one would need to justify mitigation
17 efforts?

18 The models used for the decision analysis and exposure measures calculations
19 were embodied in three computer programs (see Figure 1.2). Exposure calculations were
20 programmed in C++. A highly interactive and graphical interface was written in Visual
21 Basic to allow users to specify scenarios for transmission or distribution line
22 configurations and to write out the results of the field calculations. The configurations
23 used in this interface were identical to those developed by Enertech Consultants in a
24 separate project for the California Department of Health Services (Enertech Consultants,
25 1998a,b). The decision analysis calculations were programmed in ANALYTICA[®], a
26 software program developed by Lumina Decision Systems (1997). All three software
27 components were developed with many opportunities for users to specify and alter line
28 configurations, land use patterns, population characteristics, and many other model
29 parameters. The purpose was to facilitate sensitivity analyses and to generate insights
30 into the decision problem, not to make policy recommendations.

31 Two additional efforts were made as part of this project. The first was an
32 assessment of the environmental justice implications of alternative EMF policies
33 affecting the power grid. For this purpose a workshop on environmental justice
34 implications of EMF policies was conducted in April 1998. This workshop included
35 presentations of the leading researchers and scholars in the field of environmental justice
36 (see Appendix D). The second effort was a review of the topic of property values near
37 transmission lines and a feasibility study for a more detailed assessment of the impacts of
38 EMF policies on property values. Feasibility studies were developed by a real estate
39 appraisal firm and by an environmental economist (Parkcenter Reality Advisors, 1999;
40 Gregory, 1999).

41 While good analysis is a pre-requisite to informed policy making, it is not
42 sufficient in a situation of high scientific uncertainty and conflicting values. A *good*
43 *process* that involves stakeholders from the beginning can do much to assure that the

analysis is improved (by including the real concerns of the stakeholders) and that it is communicated better (by explaining the results to the stakeholders in their own terms). The project therefore followed a deliberate process of interacting with key stakeholders from the beginning of the project to elicit their values, suggestions for policy options, and concerns.

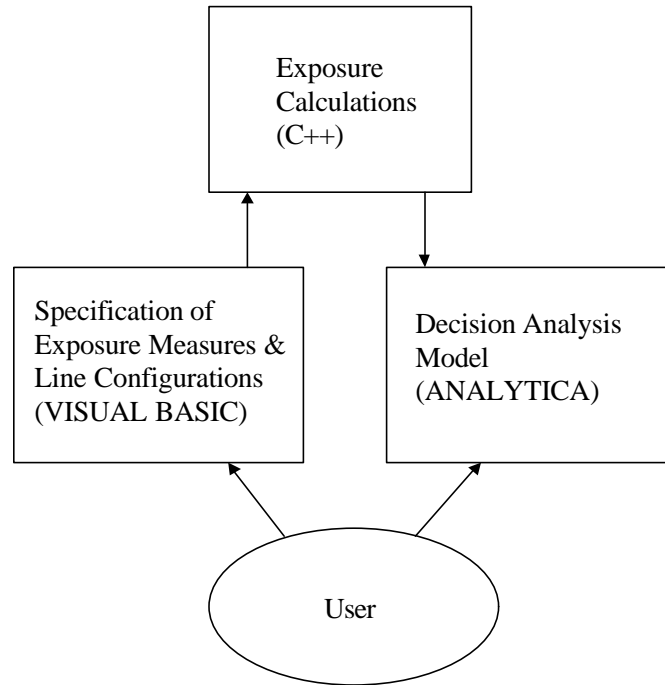


Figure 1.2: Models Developed for the Power Grid and Land Use Policy Analysis Project

The project developed the policy analysis frameworks from the “bottom up,” considering fairly specific local policy situations first, and later generalizing to statewide policies. The reason for this approach was that most decisions about the power grid are local in nature, and an appraisal of statewide regulations or policies has to be based on an analysis of their implications on these local decisions. The project developed policy analyses and associated software for four policy modules¹:

1. retrofitting existing transmission lines,
2. retrofitting existing distribution lines,
3. siting and constructing new transmission lines,
4. improving existing home grounding systems.

¹ The original proposal by Decision Insights, Inc. included another module called “Retrofitting Existing Substations” in place of the “New Transmission lines” module. However, stakeholders expressed a much stronger interest in the latter model, which was therefore substituted for the substation module.

1 For each module, two or more example scenarios were developed that described a
2 concrete decision situation. For example, three scenarios were developed for the module of
3 retrofitting existing transmission lines:

4 1a. retrofitting an existing 230 kV transmission on a clear right-of-way in a
5 moderately populated suburban environment,

6 1b. retrofitting an existing 115 kV transmission line on a clear right-of-way in a
7 densely populated urban/suburban environment,

8 1c. retrofitting an existing 69 kV transmission line located on a street side in a
9 densely populated urban/suburban environment.

10 Because of the limited data in many areas, the computer models were used primarily
11 for two purposes: 1) To determine with bounding calculations whether a particular
12 evaluation criterion mattered or not, and 2) to compare mitigation alternatives on the criteria
13 that did matter, using different sets of assumptions. For example, one criterion for evaluating
14 mitigation alternatives was the risks from pole collisions. Using assumptions that would tend
15 to magnify the effect of pole collisions, the models show that this impact is fairly small. In
16 contrast, the models show that property values have a large impact. In addition, the models
17 demonstrate, how this impact changes with different assumptions about property values.

18 Many insights were gained from running the computer models for specific modules
19 and scenarios. Some of these insights cut across modules and scenarios. For example, a
20 consistent result was that only a small number of the 39 criteria used to evaluate EMF
21 mitigation alternatives made a difference: the criteria related to expected EMF health effects,
22 the costs of mitigation, the impact on service reliability, and the impact on property values.

23 To generalize local decisions to statewide policies, we used statewide data on
24 transmission and distribution lines and extrapolated from the most typical decision situations
25 at the local level to the statewide level. This generalization necessarily used wide ranges of
26 health effects, costs, and other consequences, since the scenario analyses represented only a
27 limited subset of real-world situations.

28 The following chapters describe the project and its findings in more detail. Chapter 2
29 provides an overview of the California power grid system. Chapter 3 summarizes how
30 several workshops created the decision framework for this project. Chapter 4 describes the
31 exposure measure approach and model. Chapter 5 shows how the exposure calculations are
32 turned into risk estimates. Chapter 6 describes the cost models, while Chapter 7 shows how
33 this project estimated other major (outages, property values) and minor consequences of
34 mitigation alternatives. Chapter 8 gives an overview of the results of ten ANALYTICA[®]
35 models developed for this project. Chapter 9 considers the value of waiting for more
36 information vs. acting now to reduce fields. Chapter 10 summarizes the results of a
37 workshop on environmental justice and Chapter 11 examines the statewide implications of
38 the model results.